CAD/CAM METHODS IN SUPPORT OF HISTORIC PRESERVATION: A CASE STUDY OF THE FREEMAN HOUSE BY FRANK LLOYD WRIGHT

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Abstract
Preservationists have an impressive array of digital tools to aid them in documentation and analysis of historic structures. The tools range from near photo-realistic renderings to demonstrate what a "restored" building might have looked like at one specific time in history to complex chemical analysis of paint chips and pigments to geographic information systems used as management tools for historic properties. Computer-aided design / computer-aided manufacturing (CAD/CAM) is set of important digital aids in historic preservation efforts. This paper presents a case study of the use of CAD/CAM in support of an effort to restore a textile block house designed by Frank Lloyd Wright. CAD/CAM methods are being employed to help produce a new mold so that new textile blocks can be manufactured that match the existing blocks. An existing textile block mold was digitally scanned, digitally mirrored and edited, and will be fabricated from an aluminum billet to replace a mold that no longer exists. Although seemingly a simple process and well within current technological abilities, the work proved substantially more challenging that initially imagined.

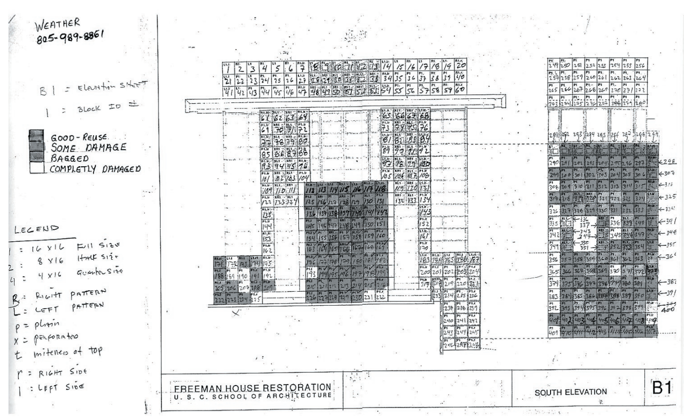
Resumen
Los preservacionistas tienen un impresionante surtido de herramientas digitales para la ayuda en la documentación y análisis de estructuras históricas. Las herramientas comprenden desde acabados fotográficos casi reales, a fin de demostrar como una edificación «restaurada» pudo haberse visto en un tiempo específico en la historia, hasta complejos análisis quimicos de fragmentos de pintura y pigmentos, así como sistemas de información geográfica usados como herramientas de manejo para propiedades históricas. Los programas de asistencia de diseño por computación / asistencia de fabricación por computación (CAD/CAM) son una importante serie de ayudas digitales en esfuerzos de preservación histórica. Este trabajo presenta un estudio del uso del CAD/CAM en apoyo a un esfuerzo para restaurar un casa diseñada por Frank Lloyd Wright. Fue construida con bloques con un patrón único a los dos lados del mismo. Los métodos CAD/CAM están siendo empleados para ayudar a producir un nuevo molde y fabricar nuevos bloques con el mismo patrón que coincidan con los bloques existentes. Un molde existente fue escaneado, reflejado y editado digitalmente para ser reproducido de un acantonamiento de aluminio para remplazar el molde que ya no existe (que es el del lado opuesto). Aunque pareciere un simple proceso y asequible mediante la tecnología actual , el trabajo demostró ser substancialmente más desafiante de lo que inicialmente se pensó.

Background
The Freeman House was designed by Frank Lloyd Wright and completed in 1923. It has been described as the clearest expression of the design rationale that underlies Wright's development of the textile block construction system. The textile blocks are custom designed, unreinforced concrete blocks; other textile block patterns have been used in creating the Hollyhock (Barnsdall), Millard, and Ennis-Brown houses. Unfortunately, time, weather, landscaping (the ivy growing on the walls), and earthquakes have taken a toll on the Freeman house. Additionally, the experimental nature of the textile blocks themselves has led to substantial degradation. Many years of efforts have been placed on stabilizing the house both structurally and materially. Currently the building has been reinforced with steel in many locations, and foundation piles have been added to prevent the house from slipping down its hill-side site. Earthquake stabilization is now almost completed on the house, and textile block replacement is underway.

Fig 1 – Interior view of the Freeman House under renovation (Photograph by Jim Kehr)

Many of the original blocks have decayed over time or been damaged by the restoration work. The highly detailed face of the textile blocks requires special manufacturing processes and attempts will be made to replace the damaged blocks using a technique similar to the original construction process where aluminum molds were used to press together the concrete mix. The house itself has been fully documented through the Historic American Buildings Survey (HABS), and three-dimensional computer models have been created that show the location and orientation of each of the thousands of textile blocks. Elevation drawings were also produced where each individual block has been categorized as to its level of damage and whether or not it needs to be replaced.

Fig 2 – Typical block identification on elevations categorizing



degree of damage

One of the original aluminum molds for the exterior face of the block still exists. However, approximately half of the textile blocks used in the house are “mirror-image” or reverse-oriented blocks. The focus of this study is on the development of a “mirror-image” mold as a complement for the existing aluminum mold. Given the existence of the first mold, and the development of highly accurate scanning and machining technology, this is an apparently simple task, and an appropriate case study of one of the uses of CAD/CAM in historic preservation. The (apparently naïve) participants imagined that this would be a relatively easy task of three-dimensional scanning, mirroring the digital model, and sending it to a multi-axis milling machine.

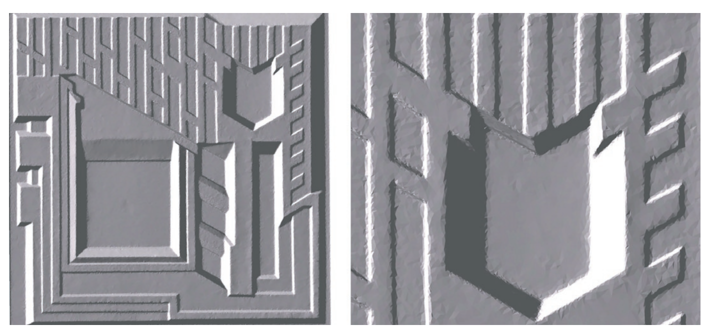
Fig 3 – Photograph of original mold

Work in Progress

For the first stage of the project, the remaining original aluminum mold was successfully scanned using a stereographic camera system to help recreate the mirror-image mold. A non-reflective, glare resistant, fine photographic powder was dusted on the mold to aid in the capture of the digital data. The scan generated a point cloud of three dimensional data that was then decimated and triangulated to create a surface-based 3D computer file. It was at this point that the first significant stumbling block was encountered; choosing what level of accuracy to convert the point cloud to a mesh; in other words, how much to decimate the data set without losing key dimensions and details.

The unique geometry of the Frank Lloyd Wright textile block design includes many primary areas of essentially planar geometry contrasted with other areas of fine detail, sharp corners and filleting. The digital model immediately revealed inadequacies in the decimation software as it was not able to accommodate the combination of the sometimes highly configured areas with the areas of plain geometry. Either the detail was well-captured and the file size became too high in the simple geometry areas, or the file size was manageable but the fine detail was lost. The problem was accentuated by the original condition of the aluminum mold that was scanned. The mold had been previously used to physically create numerous textile blocks. In doing so, it has been slightly damaged, actually subtly pitted from the construction process. The digital camera scan was picking up these irregular features, and the decimation software was not able to resolve the complexity (to a more simple model) of the digital model in a satisfactory manner.

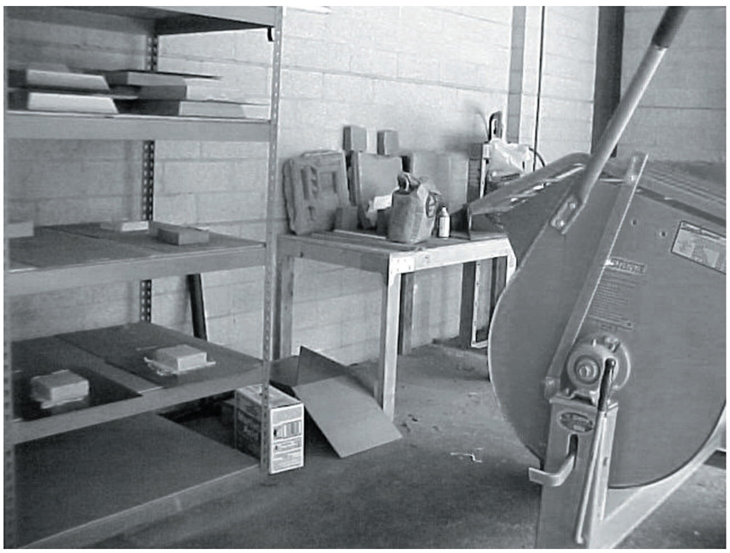
Fig 4 – Digital image of scanned mold; note that it is a mirror image of the original



The file had to be simplified for three reasons: we did not want to duplicate the pitting on the new blocks, the file size was much too large for our fabricator to handle, and the fabricator was afraid that his machinery (he was donating the time on his CAD/CAM machine) would take a tedious amount of time slowly milling the aluminum

billet as it reproduced all the pits and irregularity on the surface. Different solutions were proposed including asking the fabricator to essentially turn down the resolution on his machine; this was unworkable because then the sharp edges of the original textile block design would be lost. We are currently working on some of the other solutions: trying different versions of software to decimate the mesh (a more intelligent software program would help), paying a person to edit the file to clean it up (not exactly what we had in mind when we started the project!), or rescanning a newer version of the mold (it has other warping problems so this will probably not work). If all else fails, we could use other techniques to make an aluminum copy of the existing mold, but one of the goals of the original project was to demonstrate the usefulness (and ease!) of CAD/CAM techniques.
Fifteen months after beginning work in the CAD/CAM textile block mold project, the work is still incomplete. It has been further stymied by the loss of a key player who has moved on to another job, and the reliance upon donations of time and materials by the various companies involved. Certain aspects of the project worked as expected; it was trivial to mirror image the digital data and add additional depth so that the new mold would be deeper, and handles could be later added to it if necessary. The physical workspace for the making of the blocks is completed, and work should be underway soon in reworking the digital model of the mold to the specifications of the fabricator.

Fig 5 – Area set aside for the fabricating of new



textile blocks in the School of Architecture